SUBARCTIC AIR POLLUTION

J. Holty

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ABSTRACT

Fairbanks, Alaska is a Subarctic community in interior Alaska experiencing atmospheric conditions of high air pollution potential. Temperature inversions from the surface occur over 50% of the time. Glacial silt and forest fires can provide natural pollution sources when winds are sufficient. The degree of atmospheric stagnation becomes apparent during extreme cold spells when water emissions freeze, forming a dense canopy of ice fog. Air quality surveys have shown air pollution experienced may be more than in many large cities. With the advent of Federal (U.S.) ambient air quality standards, the quality of air in Fairbanks has been shown to require Priority I control in two categories, carbon monoxide (CO) and total suspended particulates. Average hourly CO levels have been shown to exceed the Federal standard more than half of a composite day. Wind velocity correlates moderately with CO levels. Temperature lapse rate appears to be insignificant. The dominant factor is considered to be traffic volume, which correlates directly with hour average CO concentrations. Particulate levels exceed Federal standards in geometric mean and 24-hour maximum. Particulate peaks appear during breakup and freezeup. Natural causes for particulate source are discounted and traffic indicted. Feasible control measures must address traffic as the main cause, directly or indirectly, for the Priority I classification. Abatement of the Priority I pollution will indirectly help suppress ice fog.

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SUBARCTIC AIR POLLUTION*

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Geographic Location, Population, and Climate

Fairbanks is located near 65°N latitude in the heart of interior Alaska. The city has 20,000 residents; about an equal number reside in the adjacent area. It is nestled in a basin at the confluence of the Chena and Tanana Rivers, open to the south and surrounded on the other three sides by hills rising to approximately 500 meters above the valley floor. The basin floor includes about 160 square kilometers and is approximately 125m above MSL. The mean annual surface temperature is about -3°C. Normal daily mean temperature approaches +16°C by July and -25°C in January. These values include extreme departures from normal, for the record high is +34°C and the record low -54°C.

The surface atmosphere in the Tanana Valley is often stratified. This occurs more than half of the year and is obvious enough in its effect that images are distorted on the southern horizon. Density stratification, usually resulting from radiative cooling at the surface, produces temperature inversions from the surface which are considered among the steepest experienced in the world. During this atmospheric stratification, surface winds are light, resulting from local katabatic flow and prevailing downstream gravity drainage. Upper level winds usually do not penetrate the stagnant surface pool, as in the Fairbanks basin.

Geologic Features

The Fairbanks basin was never glaciated, although the Tanana River is a large braided glacial river. While the silt overburden in the Tanana flats

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may be mostly waterborne, the overburden on the adjacent hills in the area is wind blown in origin. This simply means that the soils of the area, called loess, are extremely fine grained material. Fortunately these soils are now well vegetated and the only natural exposure of the material is on the active Tanana River.

Natural Air Pollution

There are two immediate avenues for natural air contamination in Alaska's interior: first, wind blown glacial silt, and second, smoke from forest fires. A large amount of fine surface material may be exposed by receding water on the Tanana, especially after a flood crest. Forest fires can be a significant source, as the interior summers are often dry with frequent electrical storms. Winds affect both sources proportionally.

Human Habitation and Ice Fog

With the discovery of gold in interior Alaska at the turn of the century came many people. Fairbanks became a small town which survived the boom-to-bust growth of the gold rush and began to stabilize in post-war years. Pollution was not apparent in the early mining years, but growth in the post-war years began to cause a cold weather phenomena called ice fog. With the atmosphere so often stratified, and with extremely cold temperatures, emissions of water vapor from combustion and evaporation quickly freeze forming tiny ice crystals which remain suspended in the air. With increasing water emissions, ice fog became an obstruction to visibility, a depressing condition under which to live when so cold and with so little daylight, and a distinct indication of air pollution.

Air Quality Surveillance

After several scientific investigations had been made into the nature of ice fog, two independent air quality surveys were initiated. One survey was made as a part of the nationwide National Air Surveillance Network and the other by the Arctic Health Research Center (1, 5). The National Air Surveillance Network survey is a continuing program. The Arctic Health Research Center used identical procedures as the National Air Surveillance Network and also employed other collection techniques to provide some additional information. At one location, carbon monoxide was monitored continuously for 32 consecutive winter days in February-March, 1970.

Results of Surveys

The results of the surveys indicated Fairbanks has a significant air pollution problem. Many pollutants were found in higher concentrations than in big cities, but when Federal Air Quality Standards were set and Fairbanks began to look toward a control program, the air quality figures took on their full significance.

Carbon Monoxide

Because of the results of the air quality surveys, Fairbanks will be classed as a Priority I region in both carbon monoxide and total particulate (4). It will be Priority III in all other categories so far under Federal law. Of course, this categorization does not directly relate to ice fog because it is as yet a unique problem.

The Priority I carbon monoxide classification was based on the winter monitoring data, 1970 (5). Figure 1 includes the data reduced from this

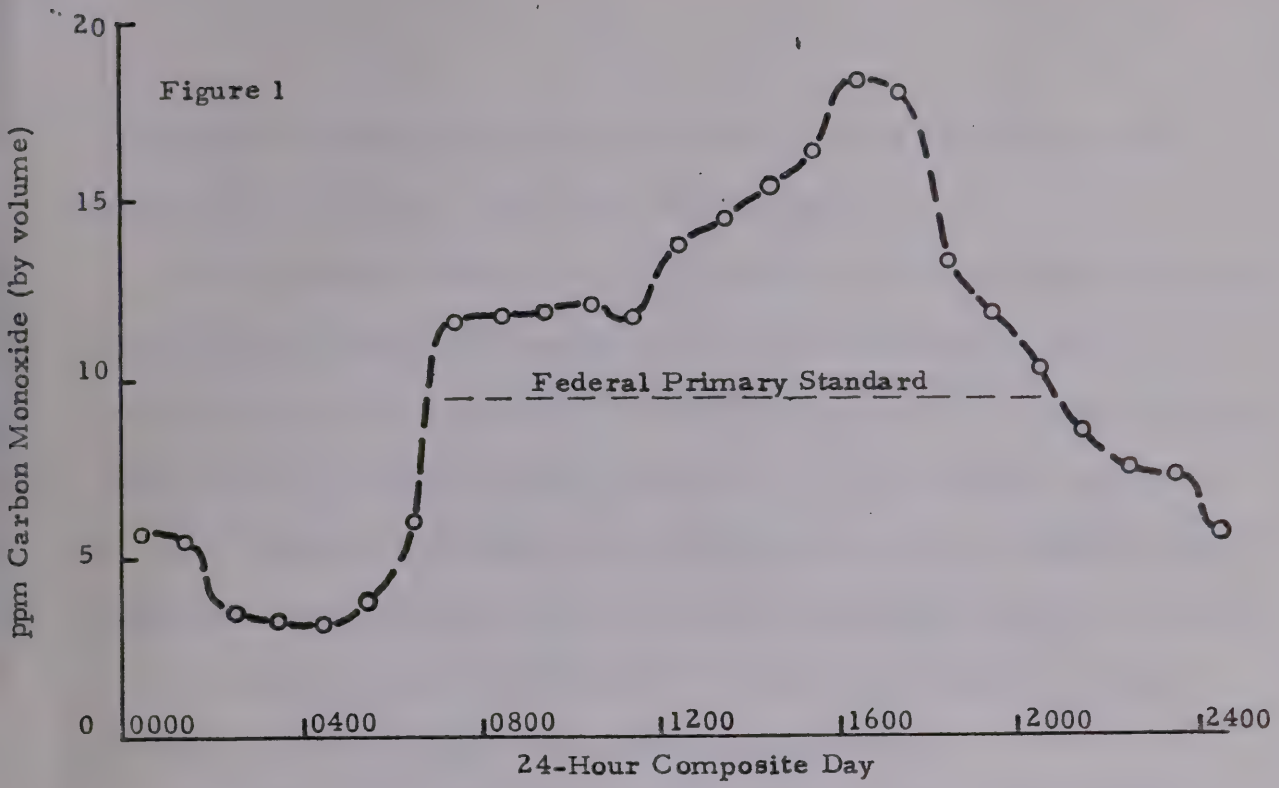
Figure I
20
15
10
5
0
Federal Primary Standard
0000
0400
0800
1200
1600
2000
2400
24-Hour Composite Day
ppm Carbon Monoxide (by volume)

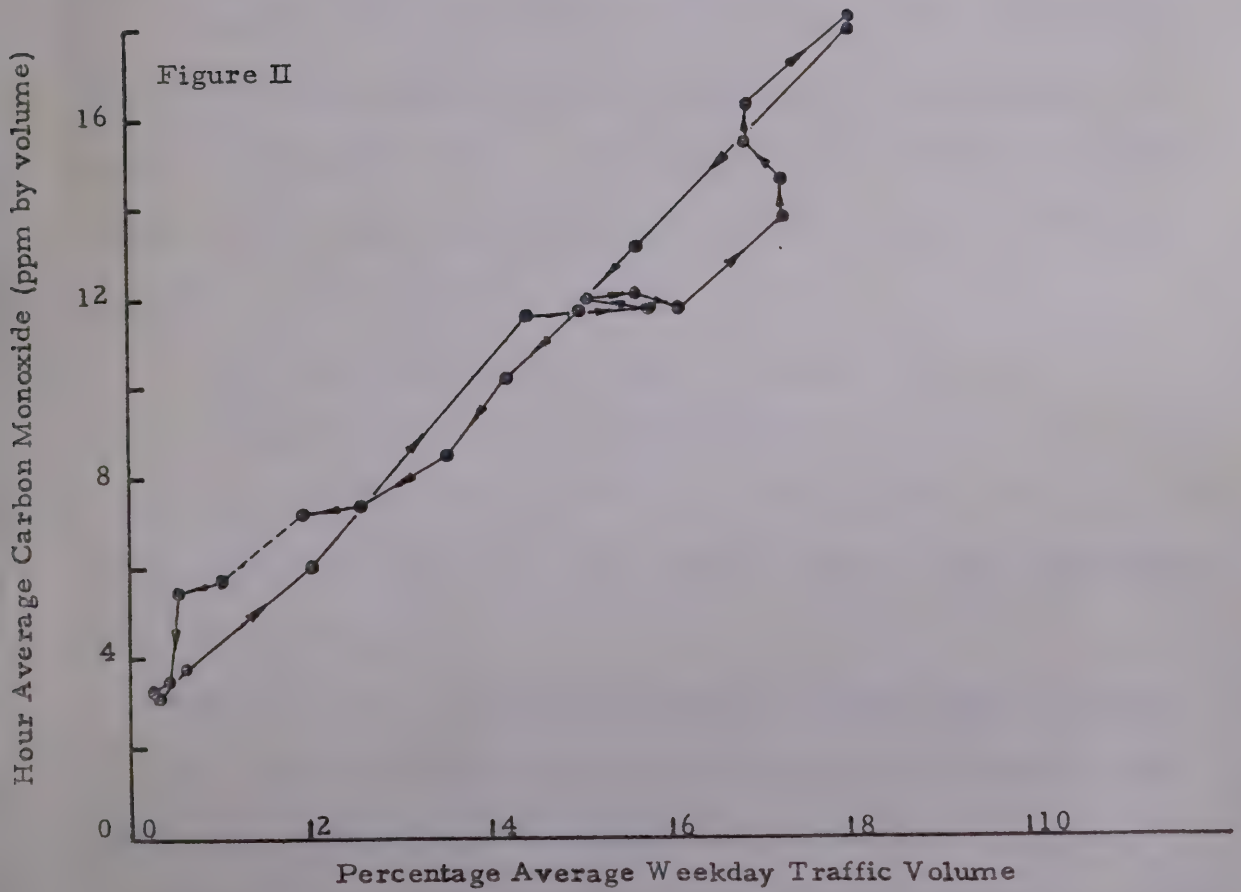
Figure II
16
12
8
4
0
0
2
4
6
8
10
Percentage Average Weekday Traffic Volume
Hour Average Carbon Monoxide (ppm by volume)

monitoring as a composite 24-hour day made up of the arithmetic average for each hour of the day from all the days monitored.

Carbon monoxide levels of the composite day exceed the Federal Primary Standard which states that 10mg/m^3 CO (9.5 ppm by volume) shall not be exceeded for an 8-hour period more than once per year (3). During this composite period, CO averages were in excess of 11 ppm for more than half of the day. Departure from this curve to the maximum hour average CO concentration which occurred during the monitoring period would represent potential CO levels which could be sustained (5). Such potential relates to episode planning, such as warning, alert, and emergency levels.

Average 3-hour wind velocity measured at the weather bureau station, some 6 kilometers distant, shows a definite 24-hour diurnal pattern, the lowest wind around 11:00 a.m. This was not thought to influence daytime buildup as correlation could not be made of weather data (U.S. Weather Bureau) and city air pollution.

Further CO monitoring was done in conjunction with measurement of local atmospheric parameters during the winter of 1970-71. Temperature was measured at five elevations from ground level to 18m above the surface. Wind velocity was measured at 23m above the surface, above all buildings in the immediate area.

Sixty-five days of the data has undergone multiple linear regression analysis using hour average CO concentration as the dependent variable and hourly wind velocity and temperature lapse rate as the independent variables. Regression coefficients were derived from regression analysis

on hour average CO concentration, CO average at 12:00 a.m. and 5:00 p.m., 4- and 8-hour buildup.

The best correlation of CO with wind and lapse rate was derived from the 12:00 a.m. and 5:00 p.m. additive, and 8-hour multiplicative relationships. These multiple correlation coefficients were ≥ 0.5. Other relationships were quite a bit poorer, but were significant enough to indicate that of the two independent variables, the regression coefficient of wind is consistently $\neq 0$, or significant. Usually the regression coefficient for temperature lapse rate was not different from zero; not a significant variable. Recent traffic analysis provides an explanation for this lack of correlation.

Shown in Figure II is a graph of hour average CO concentrations plotted against percent of average weekday traffic volume in downtown Fairbanks (same street) one block from monitoring site (6). The plot shows a direct correlation of CO with traffic. The arrows indicate order of buildup and decay. Traffic at the counter is essentially 100% of the traffic on the artery on which the sampling site is located. Without any other information, a control strategy would have to assume a traffic overhaul.

Total Particulate

Extremely high total suspended particulate measurements have led to the second Priority I classification in Fairbanks (4). Not only has the Federal Primary Standard for 24-hours been exceeded (260 $\mu g/m^3$) but the annual geometric mean has been exceeded as well (2). Annual graphs of total particulate (vs) time show high peaks usually appear during spring and fall. These peaks may be better explained as occurring breakup and freezeup.

The reasons for these particulate readings are more subtle than for carbon monoxide. The high peaks do not correlate with high winds, as this

would easily describe the natural source provided by the silt exposed on the adjacent Tanana River. The peaks do not occur within the forest fire season. A point source inventory does not explain the peaks or the other samples. The streetsupon which most traffic flows are paved.

Once again, the traffic provides the mechanism for causing high total particulate. The result of human activity in the Fairbanks area is that dust is everywhere; glacial silt and loess soil has been disturbed, uncovered and carried around by everything that moves over it. The summers are dry and warm with enough rain to spread the silt over all road surfaces, not to mention unpaved exposures. Even in the winter the same silt is on streets and parking areas. Often sand is added to minimize slippery conditions. But when combined with frozen or packed snow, particulates still may be thrown into the air.

During breakup and freezeup, it is at its worst. During these periods the temperatures are close to freezing and moisture on the surface may be slush. Slush seems to provide the optimum condition to move particulate onto the streets. When dry or frozen, either one, the silt is available for stirring into suspension in the air. The phenomena is obvious if you're looking for it. It should correlate well with the dirty appearance of the family car. The silt is so fine that it rises to considerable elevation to form a haze over the community. It is a clear, brownish, hazy halo.

Conclusion

The community of Fairbanks, isolated in the Subarctic, faces a serious air pollution problem. The problem is exemplified by a cold temperature fog condition in which water emissions freeze so rapidly that only very tiny

microscopic crystals are formed. These tiny fog particles remain suspended for long periods of time and provide a graphic illustration of the atmospheric stagnation which dominates the area. But the ice fog has been but a symptom of air pollution. Measurements discussed in this paper have verified the source of immediate concern, automotive transportation. Not only do carbon monoxide levels indict directly the traffic emission in the community, but also the degree of traffic movement is reflected by suspended particulates. Abatement of CO and particulate will indirectly accomplish a measure of control of ice fog.

Fairbanks is fortunate that a program for abatement in two Priority I categories will overlap so much. Dealing with traffic will be an integral part of control strategy. Control measures may be more easily justified when striving for the control of both CO and particulates which emanate from the same source.

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